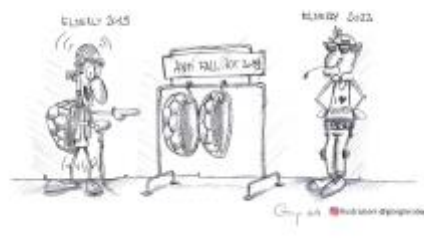




## EEG, EMG & robotics in neuro-rehabilitation



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*Gait performance and posture can be affected by aging. Falls due to lack of stability is one of the most common causes of injury and disability in the elderly. Multiple causative factors concur; older people are usually not aware of these risks and they do not report them to physicians. As a consequence, prevention of falling is often overlooked and technological solutions are proposed to detect the fall itself. The aim of this 3-y project is to develop a novel neuromuscular controller for a soft lower-limb exoskeleton to detect the loss of stability during walking or standing and apply the proper torques to restore stability. The project is structured on two consecutive phases: an offline*

*acquisition of kinematic, cerebral activity and muscular signal during over-ground gait and during postural adjustments induced by an instrumented balance platform, and an online implementation of the closed-loop controller for detecting and preventing falls. At the end of the project, we expect to deliver a robust and efficient system, that should increase the stability and the safety of elderly, with possible commercial exploitation.*

## The idea behind the Project

*Poster presented at The Hamlyn Symposium on Medical Robotics 2019 (London, UK).*

**Towards the prevention of falls in the elderly: a synergic soft exoskeleton with integrated muscle and brain biosignals to minimize gait instability\***

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**Introduction**

Gait performance and posture can be affected by aging. Falls due to lack of stability is one of the most common causes of injury and disability in the elderly [1]. Multiple causative factors concur; older people are usually not aware of these risks and they do not report them to physicians. As a consequence, prevention of falling is often overlooked and technological solutions are proposed to detect the fall itself [2]. The aim of this 3-y project is to develop a novel neuromuscular controller for a soft lower-limb exoskeleton to detect the loss of stability during walking or standing and apply the proper torques to restore stability. The project is structured on two consecutive phases: an offline acquisition of kinematic, cerebral activity and muscular signal during over-ground gait and during postural adjustments induced by an instrumented balance platform, and an online implementation of the closed-loop controller for detecting and preventing falls. At the end of the project, we expect to deliver a robust and efficient system, that should increase the stability and the safety of elderly, with possible commercial exploitation.

**Material**

**Method**

**Figure 1**

An high-density EEG setup (80 channels - Fig. 1a, s1nc; g1f1ang - Fig. 1b) will be used to record from the face and scalp (sampling frequency=1000Hz). The setup with high spatial resolution will allow to analyze the EEG signal both at the scalp level and at the source level, i.e., to reconstruct the source waveforms that generate the measured scalp topography.

**Figure 2**

Surface EMG signals will be recorded using active bipolar electrodes at sampling frequency=1000Hz (Canesta, s1 - Fig. 2b). Surface EMG will be recorded from 8 sites bilaterally (Fig. 2a). The subjects will be instrumented with 22 retro-reflective passive markers for full body motion capture, plus 2-4 markers placed on the subject's head to localize the head and register the eye position on the EMG brain images.

The exosuit compared to a traditional exoskeleton, has the wearer's joints unconstrained by external rigid structures, and the work part of the suit is extremely light. These features minimize the suit's mechanical interference with the body's natural biomechanics and allow for more synergistic interaction with the wearer.

**Figure 3**

Twenty subjects, age =  $85 \pm 5$  y.

Three different conditions (Fig. 4a):

- 1) Subject without exosuit
- 2) Subject with the exosuit OFF
- 3) Subject with the exosuit ON

to study the human-robot interaction.

Three different experimental levels (Fig. 4b):

- A. **Resting state:** 5 minutes of EEG and EMG to establish a baseline period of brain and muscle activity.
- B. **Balance trials:** 30 trials of bipedal stance for 30 s using Proton 252.
  - i.1. Static condition: 15 trials for evaluation in a static situation, with the initiation of the pressure center.
  - i.2. Bipodal stance: 15 trials for evaluation of the management of bipedal instability.
- C. **Gait trials:** 10 trials walking straight at their preferred speed; 10 trials walking straight 30% faster; 10 trials walking in a non-corridor gait course.

**Scope, Goals, Objectives**

The project is intended to accomplish the acquisition and analysis of kinematic, cerebral activity and muscular signal during gait without and with the exosuit, and the online implementation of the closed-loop controller for detecting and preventing falling phenomena. We expect the final product to be a robust and efficient system, that should increase the stability and the safety of elderly, with possible commercial exploitation.

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**References:** [1] World Health Organization, "World Report on Ageing and Health," 2015. [2] J. H. Kim, S. H. Park, and S. H. Park, "A Fall Detection System Using a Wearable Device," in *IEEE Transactions on Systems, Man, and Cybernetics - Part A*, vol. 41, no. 6, pp. 1000-1010, 2011.

**Logos:** Universidad Carlos III de Madrid, DNS, IAS-Lab, Harvard Medical School, Spaulding Research Center, Intelligent Systems Research Centre, University College Dublin, Limerick University, Trinity College Dublin, European Union, Horizon 2020, European Union, Horizon 2020, European Union, Horizon 2020.

## Webinar "Robotics in Rehabilitation" - 2nd December 2021





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### *SoftAct and PRO-GAIT projects*

*[Introduction Remarks by Alessandra Del Felice, MD, PhD - University of Padova, Dept of Neuroscience](#)*

*[Introduction Remarks by Olive Lennon, PT, PhD - University College Dublin](#)*

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Rehabilitative and assistive robots are a rapidly emerging field. However, their efficacy is still hampered by the lack of adaptive interaction with the end user, disregarding ongoing changes in brain and muscle reactivity.

The collaborative, international research projects SOFTAct and PRO-GAIT are setting the foundation to revolutionize wearable robots: artificial intelligence techniques will provide the framework to use cerebro-muscular biosignals to control robots. This will allow wearable robots to become a natural extension of the human body in the near future.

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### *[Robotics in Neuro-Rehabilitation](#)*

*[Alessandra Del Felice, MD, PhD - University of Padova, Dept of Neuroscience](#)*

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*Innovation in Rehabilitation Robotics*

*Paolo Bonato, PhD - Harvard Medical School, Phys Med and Rehab Dept*

*Walking Features before and after Exoskeleton Training*

*Roberto Di Marco, PhD - University of Padova, Dept of Neuroscience*

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*Brain Oscillations Changes after Exoskeleton Training*

*Maria Rubega, PhD - University of Padova, Dept of Neuroscience*

*Intelligent Systems for Neurorobotics*

*Emanuele Menegatti, PhD - University of Padova, Dept of Information Eng*

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*Decoding Limb Movements/Imagined Movements from EEG fro Stroke Rehabilitation*

*Damien Coyle, PhD - Ulster University*

*Neural Correlates of Learning in Brain-Machine Interface*

*Luca Tonin, PhD - University of Padova, Dept of Information Eng*

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*Concluding Remarks*

*Marco Gilli, PhD - Italian Scientific Attaché USA*

*Alessandra Del Felice, Paolo Bonato, Olive Lennon*

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## Webinar "EEG, EMG & robotics for enhancing mobility" - 3rd December 2020



### **Fostering Collaborative Work by Italian and American Researchers**

Introduction Remarks by Ugo Della Croce, PhD - Science Attaché, Embassy of Italy in Washington DC

### **Clinical Applications of Rehabilitation Robotics: Are Patients Learning from Robots?**

Catherine Adans-Dester, PT, PhD – Harvard Medical School

### **Could We Gain Clinically-Relevant Information from EEG and EMG Data Collection during Patient-Robot Interactions?**

Alessandra Del Felice, MD, PhD – University of Padova

### **Brain Oscillations Changes in Active, Passive and Imaginary Movements**

Emanuela Formaggio, PhD – University of Padova

### **Can Muscle Synergies Shed Light on the Mechanisms Underlying Motor Adaptations during Robot-Assisted Gait Training?**

Paolo Bonato, PhD – Harvard Medical School

### **Human and Robot Learning in EEG-driven Intelligent Wheelchairs**

Luca Tonin, PhD – University of Padova

### **Combining EEG and EMG Data to Control Assistive Technologies Aimed to Enhance Mobility**

Stefano Tortora – University of Padova

### **Preliminary Results on the Investigation of EEG and EMG Patterns during the Performance of Balance Tasks**

Maria Rubega, PhD and Roberto Di Marco, PhD – University of Padova

### **Concluding Remarks**

Alessandra Del Felice, MD PhD, Stefano Masiero, MD, Emanuele Menegatti, PhD – University of Padova and Paolo Bonato, PhD - Harvard Medical School